

Patterns of seabird and marine mammal carcass deposition along the central California coast, 1980–1986

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At monthly intervals from February 1980 through December 1986, a 14.5-km section of central California coastline was systematically surveyed for beach-cast carcasses of marine birds and mammals. Five hundred and fifty-four bird carcasses and 194 marine mammal carcasses were found. Common murre, western grebe, and Brandt's cormorants composed 45% of the bird total. California sea lions, sea otters, and harbor seals composed 90% of the mammal total. Several factors appeared to affect patterns of carcass deposition. The El Niño – Southern Oscillation (ENSO) of 1982–1983 was the dominant influence in terms of interannual variation in carcass deposition. During this ENSO, 56% of the seabirds and 48% of the marine mammals washed ashore. Patterns of intra-annual variation were species specific and were related to animal migration patterns, reproduction, and seasonal changes in weather. Nearshore currents and winds influenced the general area of carcass deposition, while beach substrate type and local patterns of sand deposition influenced the location of carcass deposition on a smaller spatial scale. Weekly surveys along a 1.1-km section of coastline indicated that 62% of bird carcasses and 41% of mammal carcasses remained on the beach less than 9 days. Cause of death was determined for only 8% of the carcasses. Oiling was the most common indication of cause of death in birds (6%). Neonates composed 8% of all mammal carcasses.

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De février 1980 à décembre 1986, les carcasses d'oiseaux de rivage et de mammifères marins échouées sur les plages ont été dénombrées tous les mois de façon systématique dans une section de 14,5 km le long de la côte du centre de la Californie. Cinq cent cinquante-quatre carcasses d'oiseaux et 194 carcasses de mammifères ont été inventoriées. Les Marmettes communes, les Grèbes élégants et les Cormorans de Brandt composaient 45% du total des oiseaux; les Otaries de Californie, les Loutres de mer et les Phoques communs composaient 90% du total des mammifères. Plusieurs facteurs semblent responsables de l'échouage des carcasses. L'oscillation sud du courant – El-Niño (ENSO) en 1982–1983 a été le facteur dominant de la variation inter-annuelle de l'échouage des carcasses. Durant l'oscillation, 56% des carcasses d'oiseaux de rivage et 48% des carcasses de mammifères se sont échouées sur la côte. Les variations intra-annuelles étaient spécifiques et étaient reliées aux migrations des animaux, à la reproduction et aux changements climatiques saisonniers. Les courants et les vents près de la côte avaient une influence globale sur l'échouage des carcasses, alors que le type de substrat sur les plages et les accumulations de sable à des endroits précis avaient une influence sur une plus petite échelle spatiale. Des inventaires hebdomadaires le long d'une section de 1,1 km sur la côte ont démontré que 62% des carcasses d'oiseaux et 41% des carcasses de mammifères restaient sur la côte pour moins de 9 jours. La cause de la mort n'a pu être déterminée que pour 8% des carcasses. Chez les oiseaux, l'huile sur le plumage semble avoir été la principale cause de la mort (6%). Les nouveau-nés composaient 8% de toutes les carcasses de mammifères échouées.

[Traduit par la rédaction]

Introduction

The coastal waters of California support diverse and abundant populations of marine birds and mammals, including both resident and seasonal visitors. Carcasses as well as moribund individuals frequently wash ashore and when systematically sampled for long periods of time, provide an index of seasonal and annual mortality. Such long-term data are of potential value to managers and researchers in assessing population trends. The objectives of this study were to develop species-specific indexes of mortality and identify factors that may influence rates of carcass deposition.

Methods

The study area was a 14.5-km section of coast from 0.55 km north of Point Sierra Nevada to 1.5 km north of Point San Simeon (Fig. 1). It

was subdivided from north to south into 29 consecutively numbered 500-m segments. Large-scale maps (1 : 10 000) allowed us to precisely document the location of beach-cast carcasses. The study began in February 1980 and ended in December 1986. In November 1983, substrate within each segment was classified as either rock, cobble, or sand, based on the most abundant substratum in the segment. Surveys were conducted monthly (with the southern section not surveyed in September 1983, April 1984, and June 1986) by walking the beaches during low tide. Each survey usually required 2 consecutive days and 6–7 h to complete. Field guides (Robbins et al. 1966; Daugherty 1972; Leatherwood et al. 1972; Ainley et al. 1980) were used to identify beach-cast carcasses.

Records for bird carcasses included taxon (usually species) (American Ornithologists' Union 1983), date, time, location (segment), condition, and comments. Birds were removed from the beach following data collection. Additional information for mammals included total length and sex. Entire carcasses were occasionally collected for laboratory necropsy. Sea otter (see Table 1 for scientific names of species) skulls and bacula were routinely collected. Mammals that

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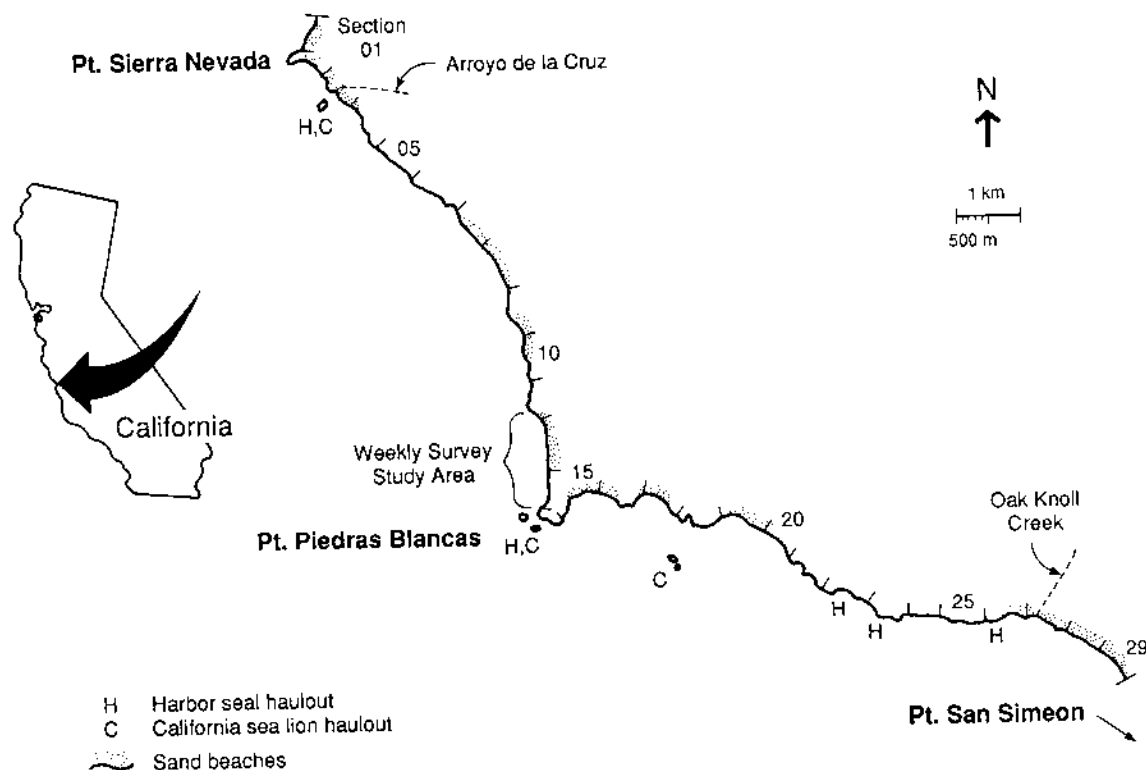


FIG. 1. The study area, showing twenty-nine 500-m sections (numbered 01–29) from north to south. H, harbor seal haulouts; C, California sea lion haulouts.

were not collected were left where found and marked with paint and (or) flagging.

Weekly surveys of a 1.1-km segment just north of Point Piedras Blancas (Fig. 1) were done from May 1983 through April 1984 to obtain an estimate of turnover rates of birds and mammals. The persistence of each carcass on a beach was estimated, assuming deposition midway between first location date and the previous survey date and a departure date midway between last location and the subsequent survey. Each carcass was marked with a museum tag and 30–60 cm of red surveyor's flagging.

Results

Marine birds

We found 554 bird carcasses representing at least 35 species during our study (Table 1); five families comprised 78% of the total. Alcids were the most common ($n = 178$), followed by cormorants ($n = 94$), grebes ($n = 68$), gulls ($n = 50$), and loons ($n = 44$). Common murres are the most abundant breeding seabird along the California coast (Sowls et al. 1980) and accounted for over 27% of the bird carcasses.

Bird carcasses occurred in pulses (10 or more birds) lasting from one to several months (Fig. 2). Sixty-two percent of the dead birds were found on 23% of the surveys. There were no apparent trends among months. June, however, is noteworthy in that it provided only 1.8% of the 554 seabird carcasses (Table 2). Variation among annual totals, however, was much greater (Table 3). Of the 19 surveys in which 10 or more carcasses were recovered, 13 were in 1982 and 1983. The mean was 79 birds/year. The years 1982 and 1983 accounted for about twice the mean, while 1984, 1985, and 1986 each accounted for about one-half of the annual mean.

At the species level there was a seasonal component to the pattern of seabird recovery rates (Table 2). Common murres

were found most frequently from July through September. Western grebes, Pacific loons, common loons, and northern fulmars were most often found during the late fall and winter, which coincides with their peak abundance off the coast (Briggs et al. 1987).

There was a seasonal component to the deposition of bird carcasses between the northern and southern halves of the study area (Fig. 3). During October through March, most birds were found in the southern portion (segments 15–29). Between April and September, most birds were found in the northern section (segments 01–14).

Deposition of bird carcasses was unevenly distributed within the study area (Fig. 4). Four sections on prominent headlands (01, 12, 13, and 15) accounted for 251 (45%) of the bird recoveries. Segments 01, 12, and 13 are oriented nearly perpendicular to the prevailing northwesterly winds of spring and summer and are composed principally of long, wide expanses of sand. Segment 15 is oriented about 90° to those segments and nearly perpendicular to the southeasterly winds that occur regularly during the winter months. Although seasonally variable, the study area was composed of about 50% sand, 40% rock, and 10% cobble. Substrate type was recorded for 132 bird carcasses. Carcasses were found more frequently on sand than would be expected if randomly distributed ($\chi^2 = 23.48$, $df = 2$, $P < 0.05$): 113 (86%) occurred on sand, 16 (12%) on rock, and 3 (2%) on cobble.

Between 13 May 1983 and 20 April 1984, 71 seabirds were found, identified, marked, and left intact in the weekly survey area (Fig. 1). The average number of days between these surveys was 8.7. Most beach-cast bird carcasses (62%) were not observed following their initial sighting. The mean number of days a seabird carcass remained on the beach was 15.6 (range 6–65).

TABLE 1. List of birds and mammals found on systematic beach walks and their proportion of the total

	No. of individuals	% of total
Birds		
Common murre (<i>Uria aalge</i>)	152	27.4
Western grebe (<i>Aechmophorus</i> spp.)	62	11.2
Unidentified cormorant (<i>Phalacrocorax</i> spp.)	38	6.9
Brandt's cormorant (<i>Phalacrocorax penicillatus</i>)	36	6.5
Unidentified gull	30	5.4
Unidentified bird	26	4.7
Pacific loon (<i>Gavia pacifica</i>)	25	4.5
Northern fulmar (<i>Fulmarus glacialis</i>)	22	4.0
Pelagic cormorant (<i>Phalacrocorax pelagicus</i>)	18	3.3
Common loon (<i>Gavia immer</i>)	17	3.1
Sooty shearwater (<i>Puffinus griseus</i>)	16	2.9
Unidentified shorebird	11	2.0
Surf scoter (<i>Melanitta perspicillata</i>)	10	1.8
Western gull (<i>Larus occidentalis</i>)	10	1.8
Brown pelican (<i>Pelecanus occidentalis</i>)	10	1.8
Cassin's auklet (<i>Ptychoramphus aleuticus</i>)	8	1.4
Pigeon guillemot (<i>Cephus columba</i>)	8	1.4
Rhinoceros auklet (<i>Cerorhinca monocerata</i>)	7	1.3
Red-necked phalarope (<i>Phalaropus lobatus</i>)	5	0.9
Glaucous-winged gull (<i>Larus glaucescens</i>)	5	0.9
Horned grebe (<i>Podiceps auritus</i>)	3	0.5
White-winged scoter (<i>Melanitta fusca</i>)	3	0.5
Eared grebe (<i>Podiceps nigricollis</i>)	3	0.5
Unidentified alcid	3	0.5
Black-legged kittiwake (<i>Rissa tridactyla</i>)	2	0.4
Double-crested cormorant (<i>Phalacrocorax auritus</i>)	2	0.4
Heermann's gull (<i>Larus heermanni</i>)	2	0.4
Red-throated loon (<i>Gavia stellata</i>)	2	0.4
Rock dove (<i>Columba livia</i>)	2	0.4
Willet (<i>Catoptrophorus semipalmatus</i>)	2	0.4
Bonaparte's gull (<i>Larus philadelphia</i>)	2	0.4
American coot (<i>Fulica americana</i>)	1	0.2
Black turnstone (<i>Arenaria melanocephala</i>)	1	0.2
California gull (<i>Larus californicus</i>)	1	0.2
California quail (<i>Callipepla californica</i>)	1	0.2
Cattle egret (<i>Bubulcus ibis</i>)	1	0.2
Herring gull (<i>Larus argentatus</i>)	1	0.2
Killdeer (<i>Charadrius vociferus</i>)	1	0.2
Snowy egret (<i>Egretta thula</i>)	1	0.2
Unidentified owl	1	0.2
Unidentified raptor	1	0.2
Unidentified scoter	1	0.2
Unidentified shearwater	1	0.2
Total	554	100.4
Mammals		
California sea lion (<i>Zalophus californianus</i>)	116	59.8
Sea otter (<i>Enhydra lutris</i>)*	33	17.0
Harbor seal (<i>Phoca vitulina</i>)	26	13.4
Northern elephant seal (<i>Mirounga angustirostris</i>)	11	5.7

TABLE 1 (concluded)

	No. of individuals	% of total
Common dolphin (<i>Delphinus delphis</i>)	2	1.0
Pacific white-sided dolphin (<i>Lagenorhynchus obliquidens</i>)	1	0.5
Rough-toothed dolphin (<i>Steno bredanensis</i>)	1	0.5
Unidentified cetacean	1	0.5
Unidentified pinniped	3	1.5
Total	194	100.0

*Twenty-three additional sea otter carcasses were removed from the study site between survey periods.

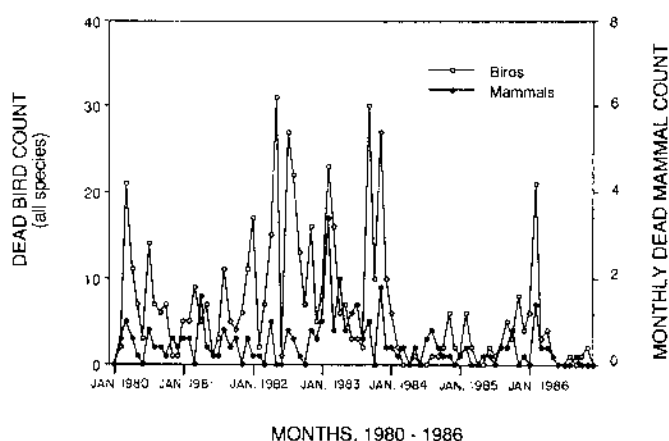


FIG. 2. Monthly counts of all species of dead birds and mammals (species combined), February 1980 through December 1986.

All birds relocated were found at or very near their original position on subsequent surveys. Species composition for weekly surveys was similar to monthly surveys.

A total of 35 birds (6.3%) were oiled, 48.5% of these were common murre. Just over 11% of the murre recovered were oiled. Other species found oiled included western grebe (3), sooty shearwater (2), Cassin's auklet (2), red-necked phalarope (2), common loon (2), northern fulmar (1), California gull (1), Bonaparte's gull (1), and rhinoceros auklet (1). One unidentified shorebird and one pigeon guillemot were apparently killed by avian predators. A Brandt's cormorant death was caused by a blue rockfish (*Sebastes mystinus*) that became lodged in the bird's throat and a monofilament fishing line entangled an unidentified cormorant.

Marine mammals

A total of 194 marine mammal carcasses, representing seven species, were found during surveys (Table 1). An additional 23 sea otter carcasses were removed from the study site between surveys. Three species (California sea lion, sea otter, and harbor seal) comprised over 90% of the total.

Temporal deposition of marine mammal carcasses was uneven (Fig. 2) and occurred in pulses similar to those observed for birds. Nearly 58% (112) of the marine mammal carcasses were found during 22% (18) of the monthly surveys. Carcass recoveries increased during late winter and early spring (Table 4). Differences among annual totals were much more dramatic than

TABLE 2. Seasonal occurrence of marine bird carcasses by taxon, years combined

	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Common murre	11	9	19	8	6	2	31	19	33	5	4	5	152
Western grebe	6	16	7	2	0	1	0	0	2	5	15	8	62
Unidentified cormorant	1	2	7	3	10	3	4	6	2	0	0	0	38
Brandt's cormorant	4	10	5	5	3	1	0	1	2	2	2	1	36
Pelagic cormorant	0	6	4	1	2	0	1	0	2	1	1	0	18
Arctic loon	4	0	5	4	1	0	0	0	0	0	8	3	25
Northern fulmar	3	2	0	0	0	0	0	1	2	5	4	5	22
Common loon	2	1	1	6	2	0	0	0	0	1	2	2	17
Sooty shearwater	0	0	0	1	15	0	0	0	0	0	0	0	16
Surf scoter	2	2	3	1	1	0	0	0	0	0	1	0	10
Western gull	0	0	1	1	4	0	0	0	3	1	0	0	10
Brown pelican	0	0	0	0	0	0	0	1	2	1	6	0	10
Other species	10	13	6	9	10	3	12	18	12	13	23	9	138
Total	43	61	58	41	54	10	48	46	60	34	66	33	554

TABLE 3. Number of bird carcasses recovered by year and taxon and annual rates of occurrence

	1980	1981	1982	1983	1984	1985	1986	Mean	Total
Common murre	24	6	64	47	0	2	9	21.7	152
Western grebe	8	8	12	12	4	5	13	8.9	62
Unidentified cormorant	22	7	5	3	0	0	1	5.4	38
Brandt's cormorant	2	8	5	15	0	3	3	5.1	36
Pelagic cormorant	1	3	3	9	1	0	1	2.6	18
Arctic loon	0	4	2	13	6	0	0	3.6	25
Northern fulmar	0	2	3	11	1	5	0	3.1	22
Common loon	3	4	5	5	0	0	0	2.4	17
Sooty shearwater	0	0	16	0	0	0	0	2.3	16
Surf scoter	2	0	5	3	0	0	0	1.4	10
Western gull	2	1	5	0	1	1	0	1.4	10
Brown pelican	0	3	0	3	0	2	2	1.4	10
Others	16	26	38	24	8	16	10	19.7	138
Total	80	72	163	145	21	34	39		554
Rate of occurrence (no. · km ⁻¹ · year ⁻¹)	5.5	5.0	11.2	10.0	1.5	2.3	2.7	5.4	

were differences among months (Table 4). The mean number of carcasses per year was 28; 1983 accounted for about 2.5 times this (69).

Sea lion carcass recoveries in 1983 accounted for 49% of all sea lions found during the study (Table 4). The sex ratio of sea lions strongly favored males (69%, $\chi^2 = 7.49$, $P < 0.05$). Of the 83 sea lion carcasses, 59 (71%) were considered subadults (TL < 180 cm). The average number of sea lion carcasses found each year was 14.5 (range 4–57).

Two peaks in the seasonal distribution of sea otter carcasses were noted, the first from January through April and another from July through September (Table 4). Pups accounted for 77% of the winter carcasses. Juveniles composed 70% of the late summer carcasses, and nearly half (46%) of all sea otter carcasses recovered were either dependent pups or juveniles (< 100 cm). The sex ratio of the 49 otters sexed was 45% males and 55% females. The average number of sea otter carcasses found each year was 8 (range 2–14).

Most harbor seal carcasses were found from January through April (73% of the total), peaking in April (38% of the total) (Table 4). Recovery rates were similar from 1980 through 1984, decreasing in 1985 and 1986. Six of the 14 animals sexed were

males. Seventy-one percent of the seals were dependent or recently weaned pups (TL < 100 cm). We found an average of 3.7 harbor seals each year (range 0–6).

Cause of death was not determined for any beach-cast mammal. Two California sea lions were oil stained, one died at or near birth, and one had lacerations that indicated a shark attack. Oil was noted on the pelage of one sea otter (3%) and two (6%) had apparent shark-inflicted wounds.

As noted for seabirds, there was a seasonal difference in the occurrence of mammals between the northern and southern segments (Fig. 3). From October through May, most mammal carcasses were found within the southern portion, but during the remainder of the year, most were in the northern half. As with birds, mammal carcasses were not distributed evenly. Six sections, 01, 12, 13, 20, 22, and 27, accounted for 98 (51%) of the 194 mammal carcasses (Fig. 4).

Of the 68 mammal carcasses where substrate type was identified, 63 (93%) were found on sand and 5 (7%) were found on rock. No mammals were found on cobble substrate.

Between 13 May 1983 and 20 April 1984, 32 marine mammals (28 California sea lions, 3 harbor seals, and 1 northern elephant seal) were found, marked, and left intact along the

TABLE 4. Number and annual rate of occurrence ($\text{no.} \cdot \text{km}^{-1} \cdot \text{year}^{-1}$) of California sea lion, sea otter, and harbor seal carcasses found during surveys as a function of month, year, sex, and age (includes 23 sea otters removed from beaches between surveys)

(A) Month

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
California sea lion	7	17	7	12	6	6	11	14	10	5	14	7	116
Sea otter	4	10	7	8	1	1	8	6	4	1	5	1	56
Harbor seal	3	3	3	10	1	2	0	0	2	1	1	0	26

(B) Year

	1980	1981	1982	1983	1984	1985	1986	Avg. no. \cdot $\text{km}^{-1} \cdot \text{year}^{-1}$
California sea lion	14 (0.97)	13 (0.90)	12 (0.83)	57 (3.9)	9 (0.62)	7 (0.48)	4 (0.28)	1.14
Sea otter	14 (0.97)	12 (0.83)	8 (0.55)	8 (0.55)	6 (0.41)	2 (0.14)	6 (0.41)	0.55
Harbor seal	4 (0.28)	6 (0.41)	5 (0.28)	4 (0.28)	6 (0.41)	0 (0.00)	1 (0.07)	0.26

(C) Sex

	Male	Female	Not determined
California sea lion	38	27	51
Sea otter	22	27	7
Harbor seal	6	8	12

(D) Age

	Young of the year	Juvenile	Subadult	Adult
California sea lion	0	17	22	22
Sea otter	13	13	3	27
Harbor seal	15	2	—	6

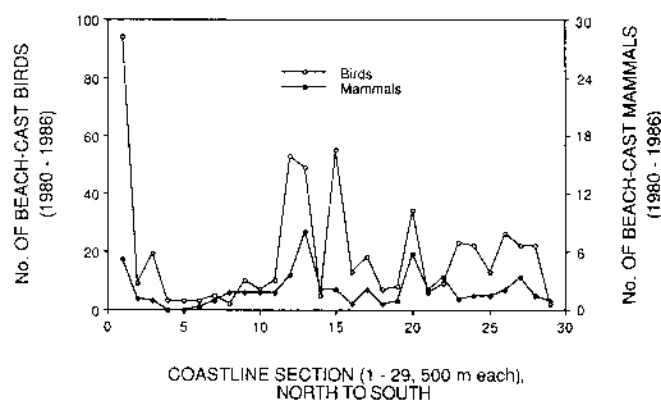


FIG. 3. The distribution of all bird and mammal carcasses within the study area, by 500-m section of coastline.

1.1 km study site at Point Piedras Blancas. The average number of days that a mammal carcass remained on the beach was 28.2 days (range 6–135). Of the 19 carcasses located more than once, 15 remained in place.

Discussion

Our results suggest that several factors regulate the deposition of a carcass on shore: (i) the occurrence of infrequent, large-scale oceanographic and meteorological perturbations; (ii)

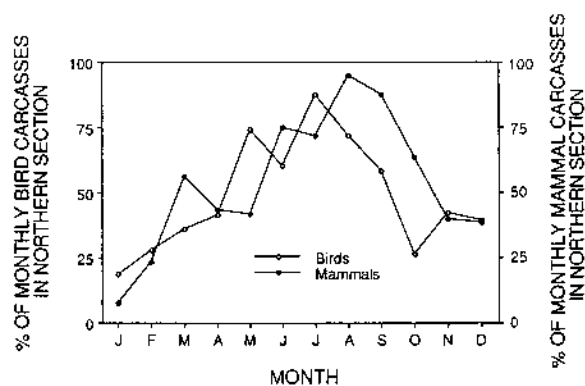


FIG. 4. The proportion of all dead birds and mammals recorded that washed ashore on the northern portion of the study area, by month, for all years combined.

seasonal changes in oceanographic and weather conditions; (iii) the abundance of live animals and their proximity to the study area, i.e., migrations, reproduction, and habitat preferences; and (iv) local physiography and beach orientation. In addition, burial, scavenging, wave action, carcass size, and stranding location may affect the persistence of a carcass once deposited.

The El Niño – Southern Oscillation (ENSO) of 1982–1983 was perhaps the strongest of this century (Cane 1983; Rasmusson 1984) and was manifested as two distinct events. First,

regular patterns of spring upwelling of nutrient-rich waters were greatly diminished, beginning in 1982, relative to normal years, as warm, oligotrophic water masses moved up from the south, dominating the coastal marine climate into 1984 (Fielder 1984; McGowan 1984). This led to reductions in nutrient availability and zooplankton production. Second, severe storms and unusually high amplitude (to 7 m), long period waves were recurrent from November 1982 through mid-March 1983 (Earle et al. 1984; Bodkin et al. 1987).

During our study, carcass deposition patterns of most seabirds appeared to be correlated with the 1982–1983 ENSO and the seasonal occurrence of a particular species. Most of the common beach-cast seabirds exhibited elevated rates of carcass deposition during this period (Table 3), although the magnitude of the effect varied among species. Reductions in prey availability, resulting from reduced primary production (McGowan 1984) provides a probable mechanism for the observed increases in carcass deposition.

While the 1982–1983 ENSO appeared to influence the abundance of beach-cast seabird carcasses, the seasonal occurrence of many species corresponded to the within-year patterns of carcass deposition we observed (Table 2). Spring and fall migrants into central California include Pacific and common loons (Briggs et al. 1987). All loon carcasses (42) were found from October through May. Eighty-nine percent of the winter residents (western grebes, northern fulmars, and surf scoters) were recovered from October through March. Shearwaters are primarily summer visitors (Briggs et al. 1987), and all shearwater carcasses were recovered during April and May of 1982. Similar seasonal patterns of carcass deposition have been reported from the north Atlantic and the eastern Pacific oceans (Simmons 1985; Heubeck 1987; Stenzel et al. 1988).

The seasonal distribution of seabird carcasses between the northern section (oriented northwest) in the spring and summer and the southern section (oriented south) in the fall and winter corresponds well with the typical circulation patterns of near-shore waters off central California. These are dominated by the wind-driven California Current, which flows southeast along the shore from April to August (Schwartzlose and Reid 1972), and results in the deposition of carcasses along beaches with a northerly exposure. Between November and February, the northward flowing Davidson Current dominates, depositing the majority of the carcasses on beaches with a southerly exposure.

Based on comparisons of our data with those of Briggs et al. (1987), beach-cast carcass deposition is not necessarily proportional to live bird abundance. Common murres, western grebes, Brandt's cormorants, northern fulmars, and Pacific loons all were found at rates four to six times greater than their relative abundance. Surf scoters, western gulls, Cassin's auklets, and brown pelicans seemed to become beach-cast in about equal proportion to their abundance. Carcasses of sooty shearwater, California's most abundant seabird (Briggs et al. 1987), were underrepresented by about 90% relative to their abundance off California. A factor contributing to these apparent differences is the distance offshore that a species normally occurs. It is probable that the farther offshore a bird dies, the less likely it is to become beach-cast (Page et al. 1982).

Average annual rates of seabird carcass deposition in our study ($5.4 \cdot \text{km}^{-1} \cdot \text{year}^{-1}$) were similar to those reported by Simmons (1985) along the western Atlantic ($5.2 \cdot \text{km}^{-1} \cdot \text{year}^{-1}$) and Heubeck (1987) near Shetland ($4.5 \cdot \text{km}^{-1} \cdot \text{year}^{-1}$), but they were higher than those reported by Speich and Wahl (1986) in Puget Sound, Washington ($2.9 \cdot \text{km}^{-1} \cdot \text{year}^{-1}$), Kuyken (1978) off

the Belgian coast ($3.7 \cdot \text{km}^{-1} \cdot \text{year}^{-1}$), or Simmons (1985) along the Gulf coast ($3.5 \cdot \text{km}^{-1} \cdot \text{year}^{-1}$).

While seabird carcass deposition was high in both 1982 and 1983, only California sea lions exhibited elevated rates of stranding (Table 4) and only in 1983. California sea lions are the most abundant marine mammals within the study area (J. L. Bodkin and R. J. Jameson, unpublished data), occurring throughout the year on three separate haul-outs near the study area (Fig. 1), and were the most common beach-cast mammal found. The observed patterns of sea lion mortality corresponded to the seasonal movement of animals to and from their breeding areas to the south (Peterson and Bartholomew 1967). Most carcasses were found prior to and following breeding as animals were migrating to and from rookeries. The apparently skewed sex ratio, favoring males, may be a result of postbreeding sexual segregation (Peterson and Bartholomew 1967).

The late winter peak in pup and adult sea otter mortality corresponds to periods of greatest winter storm activity which may promote starvation (Ames et al.)². Kenyon (1969) and Morejohn et al. (1975) noted similar patterns in Alaska and California, respectively. The late summer peak in juvenile mortality coincides with the seasonal peak in weaning of sea otter pups in California (R. J. Jameson, unpublished data).

Harbor seals occur throughout the year within the study area, with a mean maximum annual count during this study of 258 animals (J. L. Bodkin and R. J. Jameson, unpublished data). Most carcasses were found between January and April (Table 4), and most (15 of 19) were pups of the year. Late April through early May is the peak pupping period within our study area. Four of the pup carcasses were less than 75 mm TL, the lower range of size for newborn pups in British Columbia (Bigg 1969).

Only rarely could cause of death be determined. The presence of oil on a beach-cast bird or mammal was the most common indication of cause of death, although it could not usually be determined if oiling took place pre- or post-mortem. Along the shores of the north Atlantic and eastern Pacific oceans, oiling has been identified as the most common identifiable cause of death among seabirds, with rates of oiling species specific (Simmons 1985; Heubeck 1987; Stenzel et al. 1988; this study). The overall rate of oiling (6.3%) observed in our study was similar to rates reported by Simmons (1985) (8.5%), Heubeck (1987) (8.1%), and Stenzel (1988) (9.9), but much lower than those reported by Kuyken (1978) (76.7%).

During our study we observed monofilament gill nets, set in nearshore waters (<20 fathoms) (1 fathom = 1.8288 m) along our study area, entangle and drown seabirds, sea lions, sea otters, harbor seals, and gray whales (*Eschrichtius robustus*). The effect of gill nets on our results are unknown; however, Page et al. (1982) and Jameson (1984) were able to correlate entanglement mortality with the deposition of beach-cast birds and mammals. Wendell et al. (1986) suggest that net entanglement may have significantly contributed to the lack of growth in the California sea otter population between 1973 and 1983.

Our estimates of persistence of seabirds (15.6 days) and marine mammals (28.2 days) once beach-cast are probably biased high because some carcasses may have been deposited and removed between surveys. Kuyken (1978) found seabirds to persist for about 10 days on beaches off the Belgian coast. We

²J. A. Ames, R. A. Hardy, F. E. Weddell, and J. J. Geibel. 1983. Sea otter mortality in California. Unpublished report of the California Department of Fish and Game, Sacramento.

suggest daily surveys may provide a better estimate of carcass persistence.

Since all dead seabirds and marine mammals do not wash ashore, and those that do remain for varying periods, we suggest the principal value of systematic surveys is that they provide a relative index of mortality which is useful in defining long-term trends in population dynamics. In addition, the sex and age composition of the carcasses may provide a comparison with or an indication of the structure of a live population.

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